

INA111

High Speed FET-Input INSTRUMENTATION AMPLIFIER

FEATURES

- FET INPUT: $I_B = 20\text{pA max}$
- HIGH SPEED: $T_s = 4\mu\text{s (G = 100, 0.01\%)}$
- LOW OFFSET VOLTAGE: $500\mu\text{V max}$
- LOW OFFSET VOLTAGE DRIFT: $5\mu\text{V}/^\circ\text{C max}$
- HIGH COMMON-MODE REJECTION: 106dB min
- 8-PIN PLASTIC DIP, SOL-16 SOIC

APPLICATIONS

- MEDICAL INSTRUMENTATION
- DATA ACQUISITION

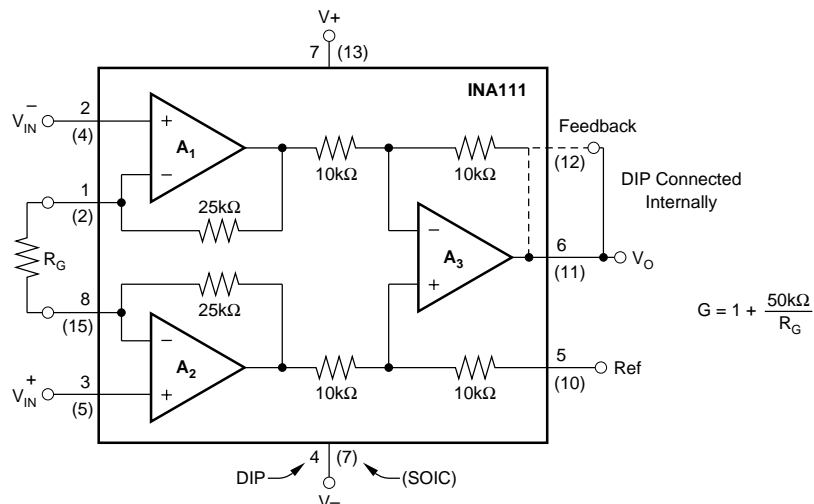
DESCRIPTION

The INA111 is a high speed, FET-input instrumentation amplifier offering excellent performance.

The INA111 uses a current-feedback topology providing extended bandwidth (2MHz at $G = 10$) and fast settling time ($4\mu\text{s}$ to 0.01% at $G = 100$). A single external resistor sets any gain from 1 to over 1000.

Offset voltage and drift are laser trimmed for excellent DC accuracy. The INA111's FET inputs reduce input bias current to under 20pA, simplifying input filtering and limiting circuitry.

The INA111 is available in 8-pin plastic DIP, and SOL-16 surface-mount packages, specified for the -40°C to $+85^\circ\text{C}$ temperature range.



SPECIFICATIONS

ELECTRICAL

At $T_A = +25^\circ\text{C}$, $V_S = \pm 15\text{V}$, $R_L = 2\text{k}\Omega$, unless otherwise noted.

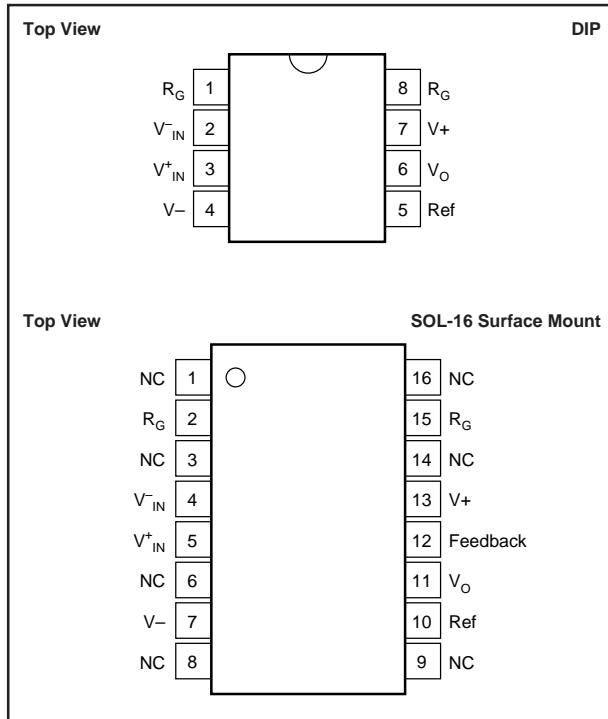
PARAMETER	CONDITIONS	INA111BP, BU			INA111AP, AU			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
INPUT								
Offset Voltage, RTI								
Initial	$T_A = +25^\circ\text{C}$		$\pm 100 \pm 500/\text{G}$	$\pm 500 \pm 2000/\text{G}$		$\pm 200 \pm 500/\text{G}$	$\pm 1000 \pm 5000/\text{G}$	μV
vs Temperature	$T_A = T_{\text{MIN}}$ to T_{MAX}		$\pm 2 \pm 10/\text{G}$	$\pm 5 \pm 100/\text{G}$		$\pm 2 \pm 20/\text{G}$	$\pm 10 \pm 100/\text{G}$	$\mu\text{V}/^\circ\text{C}$
vs Power Supply	$V_S = \pm 6\text{V}$ to $\pm 18\text{V}$		$2 + 10/\text{G}$	$30 + 100/\text{G}$		*	*	$\mu\text{V}/\text{V}$
Impedance, Differential			$10^{12} \parallel 6$			*	*	$\Omega \parallel \text{pF}$
Common-Mode			$10^{12} \parallel 3$			*	*	$\Omega \parallel \text{pF}$
Input Common-Mode Range	$V_{\text{DIFF}} = 0\text{V}$	± 10	± 12		*	*		V
Common-Mode Rejection	$V_{\text{CM}} = \pm 10\text{V}$, $\Delta R_S = 1\text{k}\Omega$							
	$G = 1$	80	90		75	*		dB
	$G = 10$	96	110		90	*		dB
	$G = 100$	106	115		100	*		dB
	$G = 1000$	106	115		100	*		dB
BIAS CURRENT			± 2	± 20		*	*	pA
OFFSET CURRENT			± 0.1	± 10		*	*	pA
NOISE VOLTAGE, RTI	$G = 1000$, $R_S = 0\Omega$							
$f = 100\text{Hz}$			13			*		$\text{nV}/\sqrt{\text{Hz}}$
$f = 1\text{kHz}$			10			*		$\text{nV}/\sqrt{\text{Hz}}$
$f = 10\text{kHz}$			10			*		$\text{nV}/\sqrt{\text{Hz}}$
$f_B = 0.1\text{Hz}$ to 10Hz			1			*		$\mu\text{Vp-p}$
Noise Current								
$f = 10\text{kHz}$			0.8			*		$\text{fA}/\sqrt{\text{Hz}}$
GAIN								
Gain Equation			$1 + (50\text{k}\Omega/R_G)$			*		V/V
Range of Gain		1		10000	*		*	V/V
Gain Error	$G = 1$, $R_L = 10\text{k}\Omega$		± 0.01	± 0.02		*	0.05	%
	$G = 10$, $R_L = 10\text{k}\Omega$		± 0.1	± 0.5		*	*	%
	$G = 100$, $R_L = 10\text{k}\Omega$		± 0.15	± 0.5		*	± 0.7	%
	$G = 1000$, $R_L = 10\text{k}\Omega$		± 0.25	± 1		*	± 2	%
Gain vs Temperature	$G = 1$		± 1	± 10		*	*	$\text{ppm}/^\circ\text{C}$
50k Ω Resistance ⁽¹⁾			± 25	± 100		*	*	$\text{ppm}/^\circ\text{C}$
Nonlinearity	$G = 1$		± 0.0005	± 0.005		*	*	% of FSR
	$G = 10$		± 0.001	± 0.005		*	± 0.01	% of FSR
	$G = 100$		± 0.001	± 0.005		*	± 0.01	% of FSR
	$G = 1000$		± 0.005	± 0.02		*	± 0.04	% of FSR
OUTPUT								
Voltage	$I_O = 5\text{mA}$, T_{MIN} to T_{MAX}	± 11	± 12.7		*	*		V
Load Capacitance Stability			1000			*		pF
Short Circuit Current			$+30/-25$			*		mA
FREQUENCY RESPONSE								
Bandwidth, -3dB	$G = 1$		2			*		MHz
	$G = 10$		2			*		MHz
	$G = 100$		450			*		kHz
	$G = 1000$		50			*		kHz
Slew Rate	$V_O = \pm 10\text{V}$, $G = 2$ to 100		17			*		V/ μs
Settling Time, 0.01%	$G = 1$		2			*		μs
	$G = 10$		2			*		μs
	$G = 100$		4			*		μs
	$G = 1000$		30			*		μs
Overload Recovery	50% Overdrive		1			*		μs
POWER SUPPLY								
Voltage Range		± 6	± 15	± 18	*	*	*	V
Current	$V_{\text{IN}} = 0\text{V}$		± 3.3	± 4.5		*	*	mA
TEMPERATURE RANGE								
Specification		-40		85	*		*	$^\circ\text{C}$
Operating		-40		125	*		*	$^\circ\text{C}$
θ_{JA}			100			*		$^\circ\text{C}/\text{W}$

* Specification same as INA111BP.

NOTE: (1) Temperature coefficient of the "50k Ω " term in the gain equation.

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PIN CONFIGURATIONS



ABSOLUTE MAXIMUM RATINGS⁽¹⁾

Supply Voltage	±18V
Input Voltage Range	(V ₋) -0.7V to (V ₊) +15V
Output Short-Circuit (to ground)	Continuous
Operating Temperature	-40°C to +125°C
Storage Temperature	-40°C to +125°C
Junction Temperature	+150°C
Lead Temperature (soldering, 10s)	+300°C

NOTE: Stresses above these ratings may cause permanent damage.

ELECTROSTATIC DISCHARGE SENSITIVITY

This integrated circuit can be damaged by ESD. Burr-Brown recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

ORDERING INFORMATION

PRODUCT	PACKAGE	TEMPERATURE RANGE
INA111AP	8-Pin Plastic DIP	-40°C to +85°C
INA111BP	8-Pin Plastic DIP	-40°C to +85°C
INA111AU	SOL-16 Surface-Mount	-40°C to +85°C
INA111BU	SOL-16 Surface-Mount	-40°C to +85°C

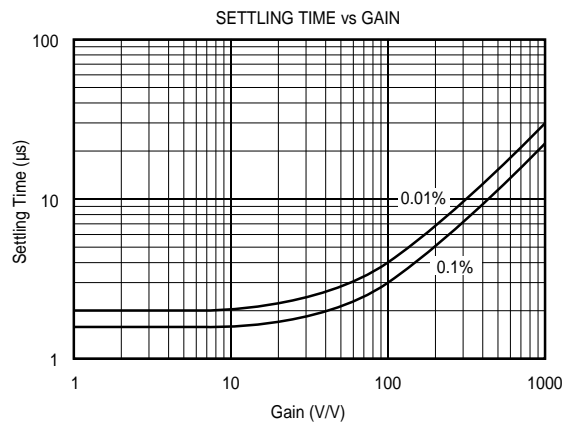
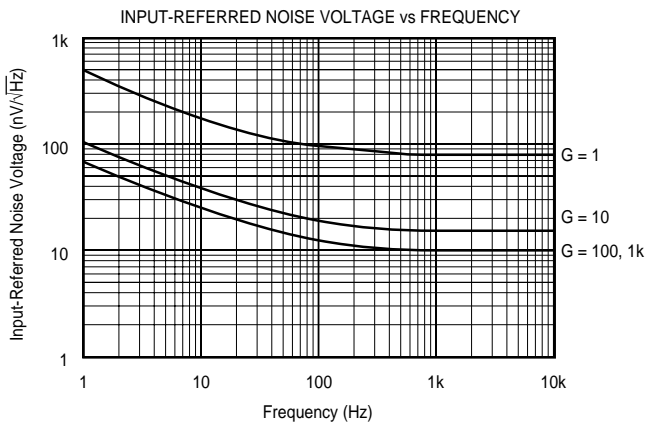
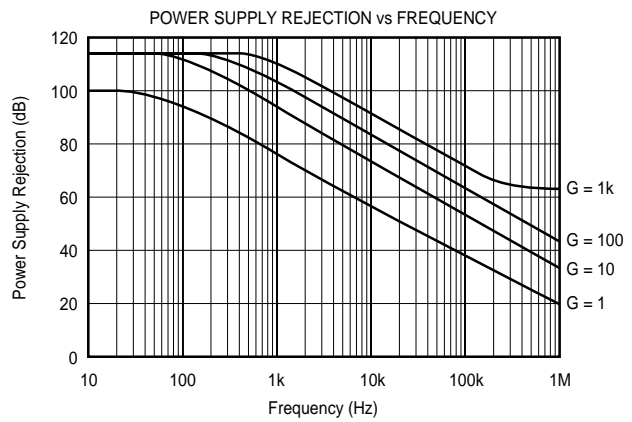
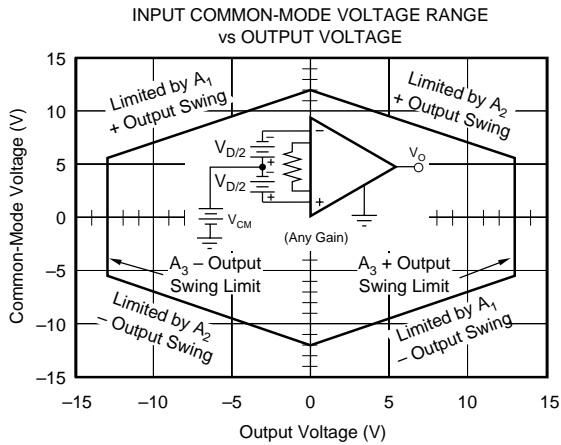
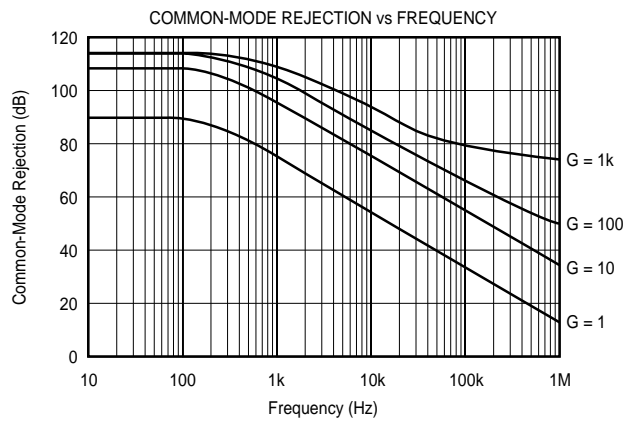
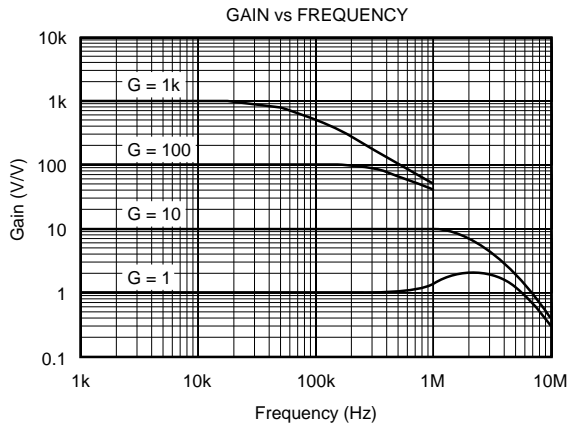
PACKAGE INFORMATION

PRODUCT	PACKAGE	PACKAGE DRAWING NUMBER ⁽¹⁾
INA111AP	8-Pin Plastic DIP	006
INA111BP	8-Pin Plastic DIP	006
INA111AU	16-Pin Surface Mount	211
INA111BU	16-Pin Surface Mount	211

NOTE: (1) For detailed drawing and dimension table, please see end of data sheet, or Appendix C of Burr-Brown IC Data Book.

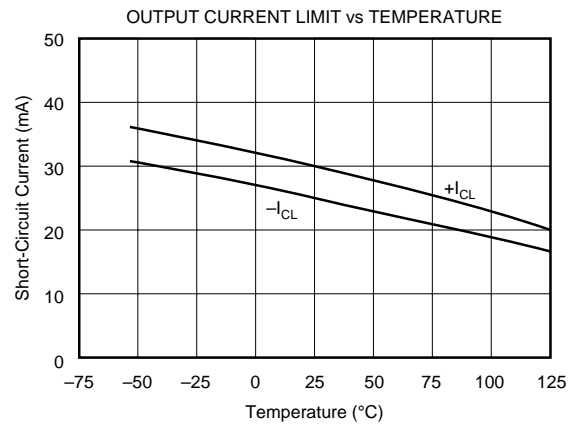
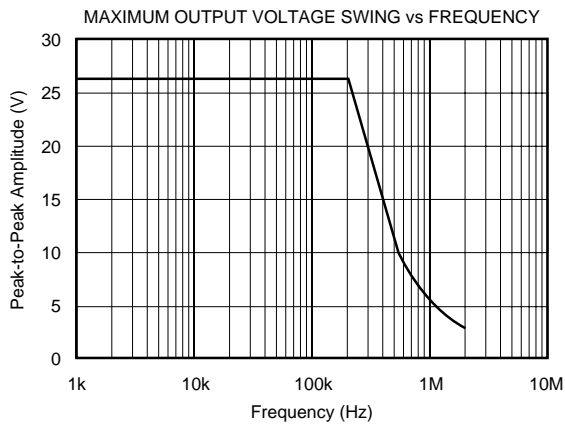
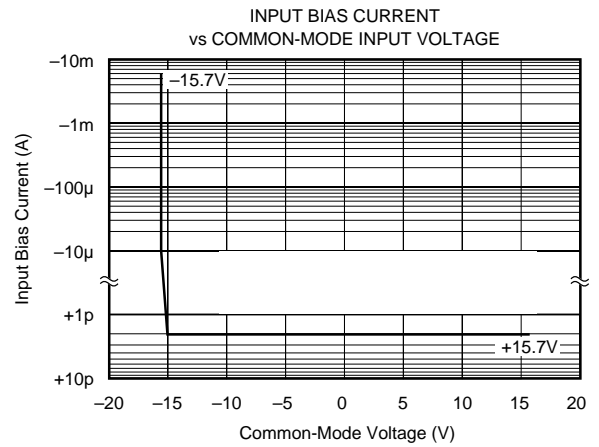
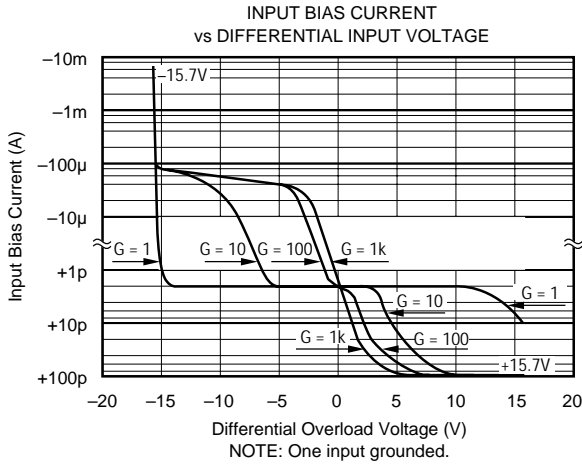
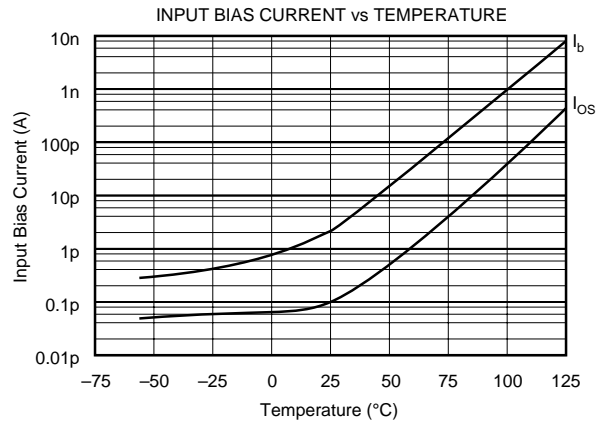
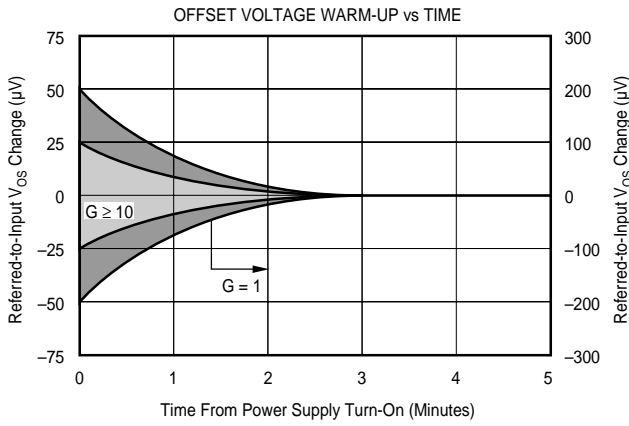
TYPICAL PERFORMANCE CURVES

At $T_A = +25^\circ\text{C}$, $V_S = \pm 15\text{V}$, unless otherwise noted.



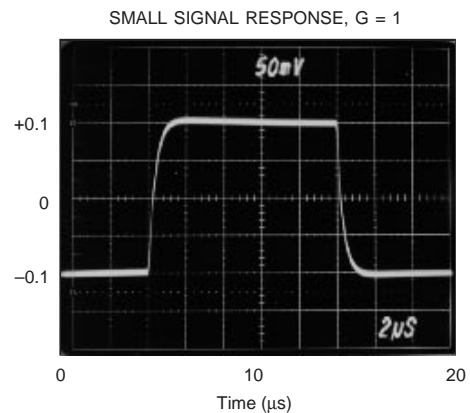
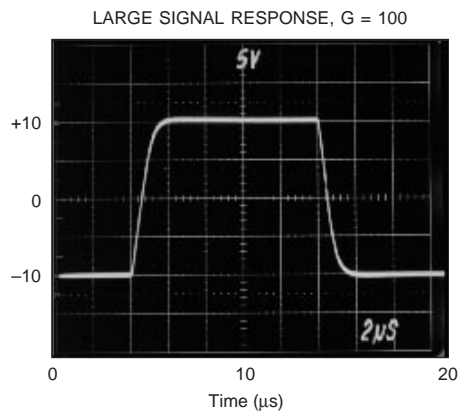
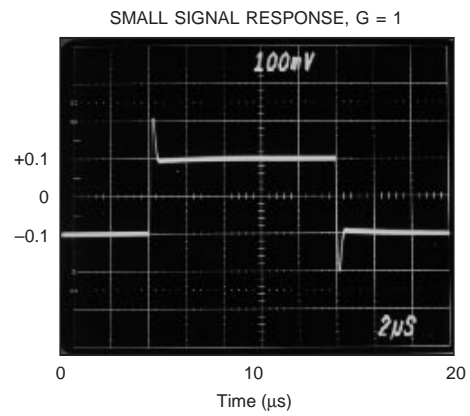
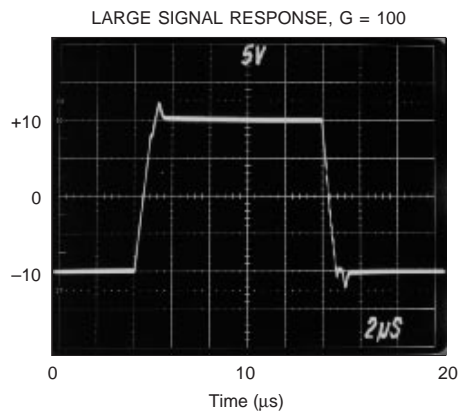
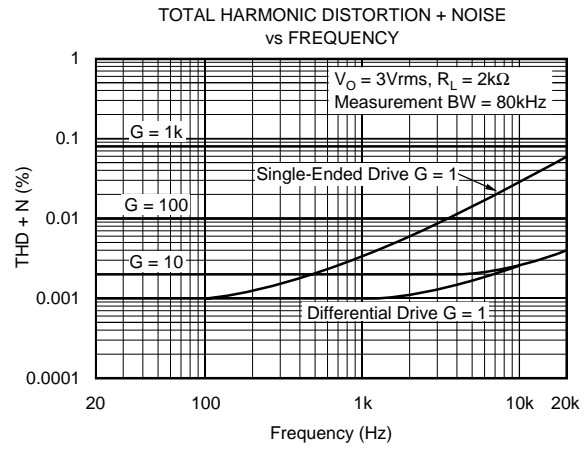
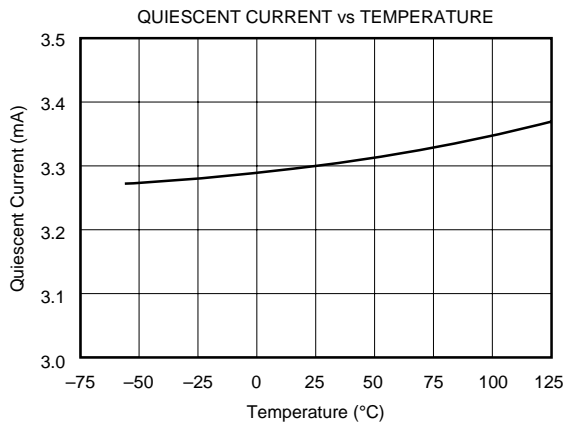
TYPICAL PERFORMANCE CURVES (CONT)

At $T_A = +25^\circ\text{C}$, $V_S = \pm 15\text{V}$, unless otherwise noted.



TYPICAL PERFORMANCE CURVES (CONT)

At $T_A = +25^\circ\text{C}$, $V_S = \pm 15\text{V}$, unless otherwise noted.



APPLICATION INFORMATION

Figure 1 shows the basic connections required for operation of the INA111. Applications with noisy or high impedance power supplies may require decoupling capacitors close to the device pins as shown.

The output is referred to the output reference (Ref) terminal which is normally grounded. This must be a low-impedance connection to assure good common-mode rejection. A resistance of 2Ω in series with the Ref pin will cause a typical device with 90dB CMR to degrade to approximately 80dB CMR ($G = 1$).

SETTING THE GAIN

Gain of the INA111 is set by connecting a single external resistor, R_G :

$$G = 1 + \frac{50k\Omega}{R_G} \quad (1)$$

Commonly used gains and resistor values are shown in Figure 1.

The 50kΩ term in equation 1 comes from the sum of the two internal feedback resistors. These are on-chip metal film resistors which are laser trimmed to accurate absolute values. The accuracy and temperature coefficient of these resistors are included in the gain accuracy and drift specifications of the INA111.

The stability and temperature drift of the external gain setting resistor, R_G , also affects gain. R_G 's contribution to gain accuracy and drift can be directly inferred from the gain equation (1). Low resistor values required for high gain can make wiring resistance important. Sockets add to the wiring resistance, which will contribute additional gain error (possibly an unstable gain error) in gains of approximately 100 or greater.

DYNAMIC PERFORMANCE

The typical performance curve "Gain vs Frequency" shows that the INA111 achieves wide bandwidth over a wide range of gain. This is due to the current-feedback topology of the INA111. Settling time also remains excellent over wide gains.

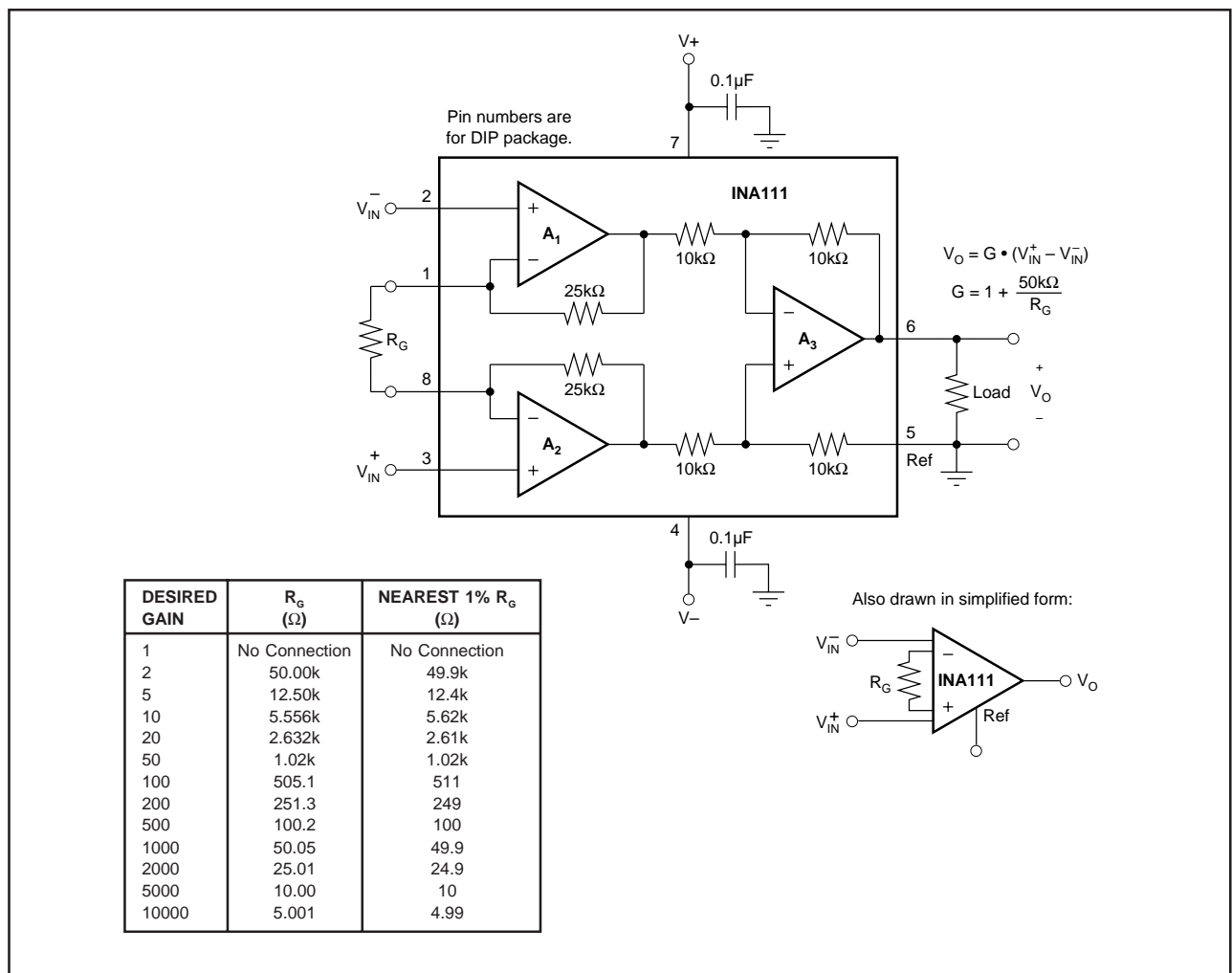


FIGURE 1. Basic Connections

A combination of common-mode and differential input voltage can cause the output of A_1 or A_2 to saturate. Figure 4 shows the output voltage swing of A_1 and A_2 expressed in terms of a common-mode and differential input voltages. For applications where input common-mode range must be maximized, limit the output voltage swing by connecting the INA111 in a lower gain (see performance curve "Input Common-Mode Voltage Range vs Output Voltage"). If necessary, add gain after the INA111 to increase the voltage swing.

Input-overload often produces an output voltage that appears normal. For example, consider an input voltage of +14V on one input and +15V on the other input will obviously exceed the linear common-mode range of both input amplifiers. Since both input amplifiers are saturated to the nearly the same output voltage limit, the difference voltage measured by the output amplifier will be near zero. The output of the INA111 will be near 0V even though both inputs are overloaded.

INPUT PROTECTION

Inputs of the INA111 are protected for input voltages from 0.7V below the negative supply to 15V above the positive power supply voltages. If the input current is limited to less than 1mA, clamp diodes are not required; internal junctions will clamp the input voltage to safe levels. If the input source can supply more than 1mA, use external clamp diodes as shown in Figure 5. The source current can be limited with series resistors R_1 and R_2 as shown. Resistor values greater than 10k Ω will contribute noise to the circuit.

A diode formed with a 2N4117A transistor as shown in Figure 5 assures low leakage. Common signal diodes such as

the 1N4148 may have leakage currents far greater than the input bias current of the INA111 and are usually sensitive to light.

INPUT FILTERING

The INA111's FET input allows use of an R/C input filter without creating large offsets due to input bias current. Figure 6 shows proper implementation of this input filter to preserve the INA111's excellent high frequency common-mode rejection. Mismatch of the common-mode input capacitance (C_1 and C_2), either from stray capacitance or

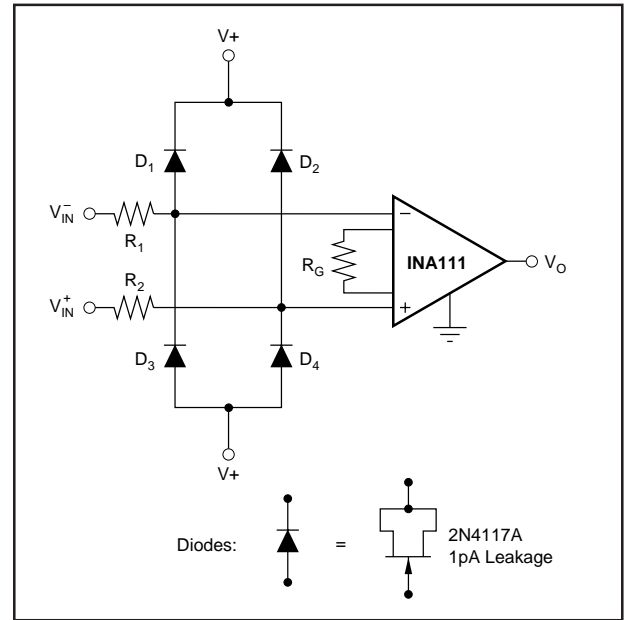


FIGURE 5. Input Protection Voltage Clamp.

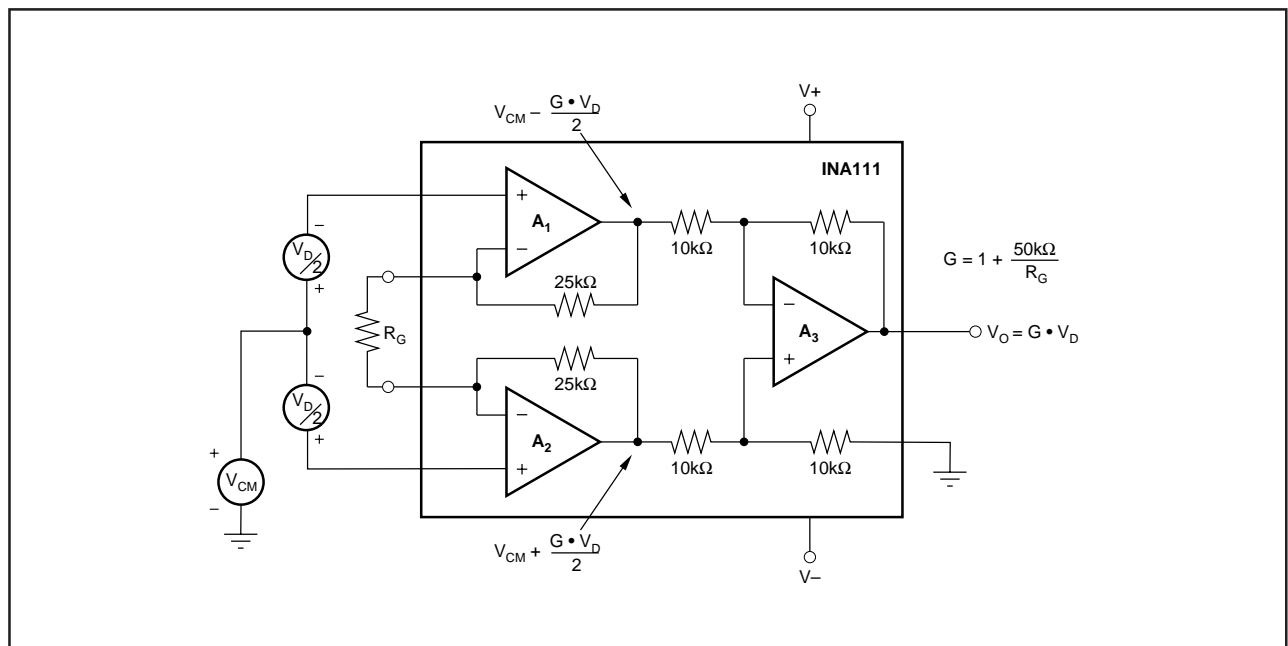


FIGURE 4. Voltage Swing of A_1 and A_2 .

mismatched values, causes a high frequency common-mode signal to be converted to a differential signal. This degrades common-mode rejection. The differential input capacitor, C_3 , reduces the bandwidth and mitigates the effects of mismatch in C_1 and C_2 . Make C_3 much larger than C_1 and C_2 . If properly matched, C_1 and C_2 also improve CMR.

OUTPUT VOLTAGE SENSE (SOL-16 Package Only)

The surface-mount version of the INA111 has a separate output sense feedback connection (pin 12). Pin 12 must be connected, usually to the output terminal, pin 11, for proper operation. (This connection is made internally on the DIP version of the INA111.)

The output feedback connection can be used to sense the output voltage directly at the load for best accuracy. Figure 8 shows how to drive a load through series interconnection resistance. Remotely located feedback paths may cause instability. This can be generally be eliminated with a high frequency feedback path through C_1 .

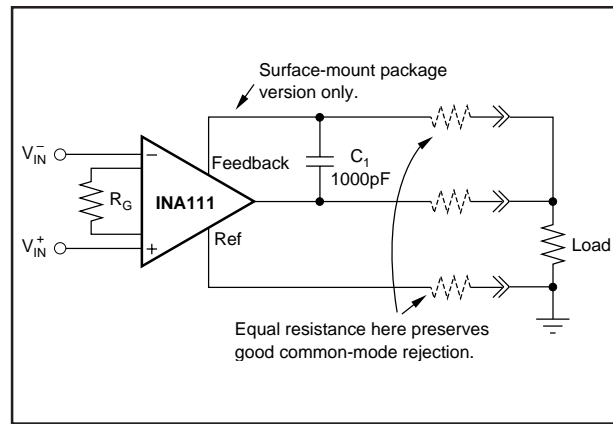


FIGURE 8. Remote Load and Ground Sensing.

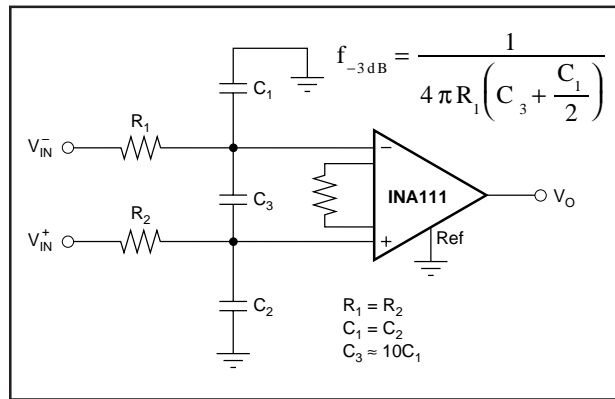
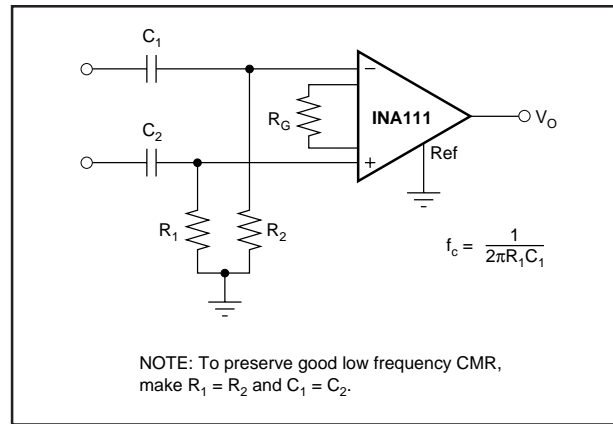


FIGURE 6. Input Low-Pass Filter.



NOTE: To preserve good low frequency CMR, make $R_1 = R_2$ and $C_1 = C_2$.

FIGURE 9. High-Pass Input Filter.

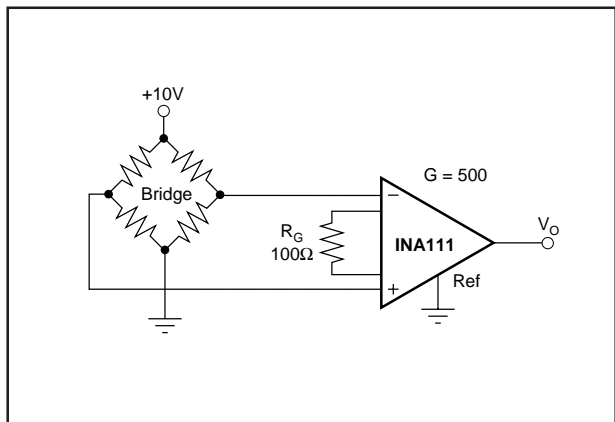


FIGURE 7. Bridge Transducer Amplifier.

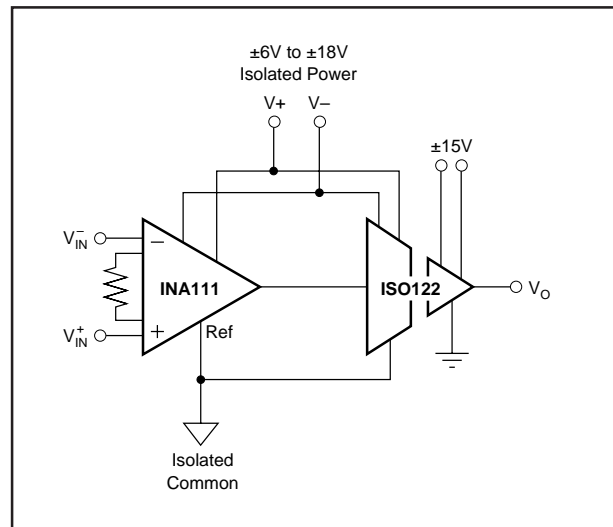


FIGURE 10. Galvanically Isolated Instrumentation Amplifier.

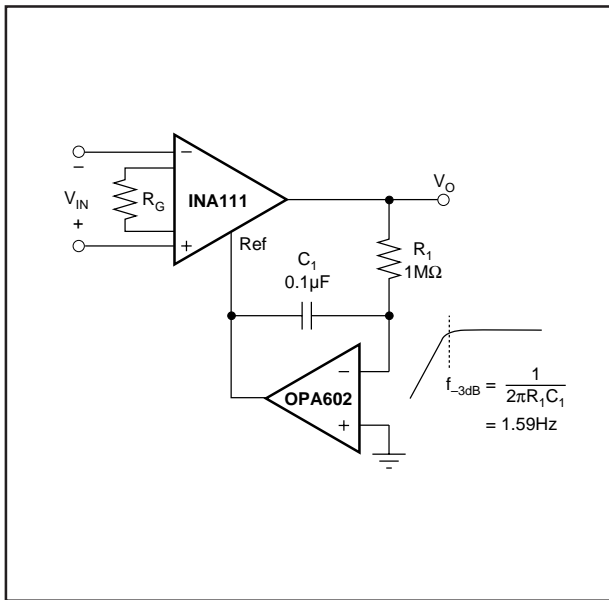


FIGURE 11. AC-Coupled Instrumentation Amplifier.

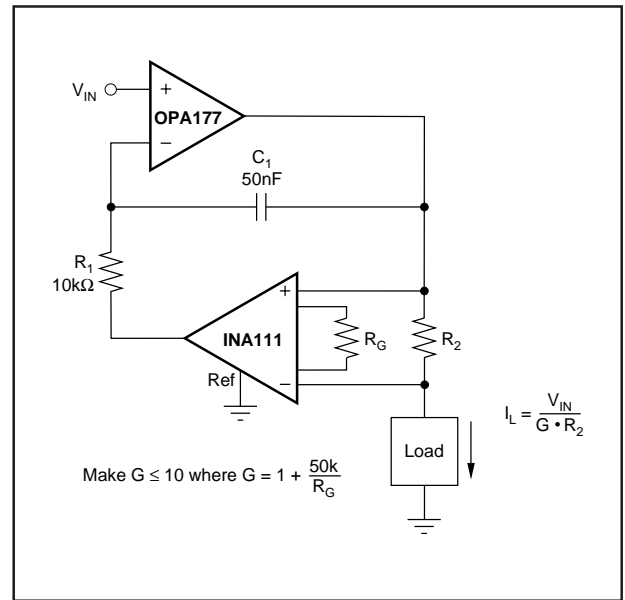


FIGURE 12. Voltage Controlled Current Source.

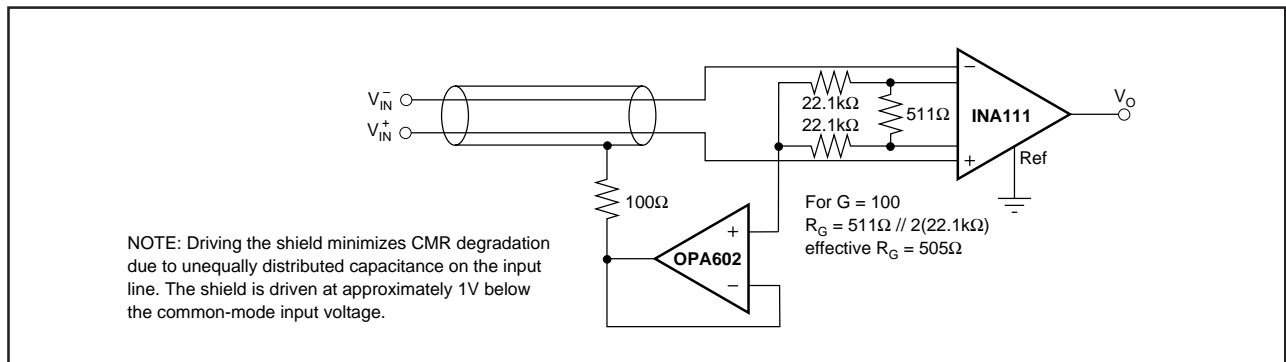


FIGURE 13. Shield Driver Circuit.

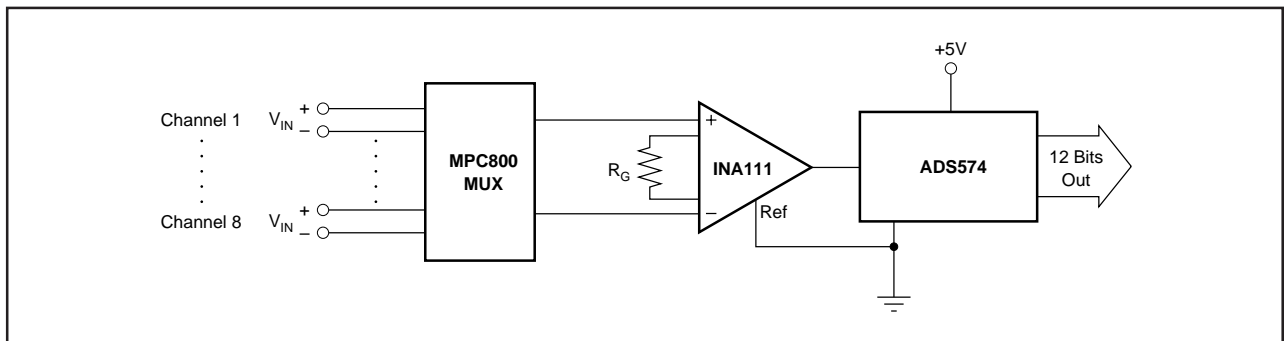


FIGURE 14. Multiplexed-Input Data Acquisition System.

PACKAGING INFORMATION

Orderable Device	Status ⁽¹⁾	Package Type	Package Drawing	Pins	Package Qty	Eco Plan ⁽²⁾	Lead/Ball Finish	MSL Peak Temp ⁽³⁾
INA111AP	ACTIVE	PDIP	P	8	50	Green (RoHS & no Sb/Br)	CU NIPDAU	N / A for Pkg Type
INA111APG4	ACTIVE	PDIP	P	8	50	Green (RoHS & no Sb/Br)	CU NIPDAU	N / A for Pkg Type
INA111AU	ACTIVE	SOIC	DW	16	48	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR
INA111AU/1K	ACTIVE	SOIC	DW	16	1000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR
INA111AU/1KE4	ACTIVE	SOIC	DW	16	1000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR
INA111AU/1KG4	ACTIVE	SOIC	DW	16	1000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR
INA111AUE4	ACTIVE	SOIC	DW	16	48	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR
INA111BP	ACTIVE	PDIP	P	8	50	Green (RoHS & no Sb/Br)	CU NIPDAU	N / A for Pkg Type
INA111BPG4	ACTIVE	PDIP	P	8	50	Green (RoHS & no Sb/Br)	CU NIPDAU	N / A for Pkg Type
INA111BU	ACTIVE	SOIC	DW	16	48	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR
INA111BUE4	ACTIVE	SOIC	DW	16	48	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR

⁽¹⁾ The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

OBsolete: TI has discontinued the production of the device.

⁽²⁾ Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

TBD: The Pb-Free/Green conversion plan has not been defined.

Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

⁽³⁾ MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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TAPE AND REEL INFORMATION



QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
INA111AU/1K	SOIC	DW	16	1000	330.0	16.4	10.85	10.8	2.7	12.0	16.0	Q1

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
INA111AU/1K	SOIC	DW	16	1000	346.0	346.0	33.0

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